

### **REMARKS**

Claims 4, 7, 9-20, and 22-24 remain in the application. Claims 4, 11, 19, and 24 have been amended; and claim 21 has been cancelled in this amendment.

#### **I. SUMMARY OF THE JUNE 4TH, 2003 OFFICE ACTION**

##### **Section 103 Rejections**

Claims 4, 7, and 9-18 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Li et al. U.S. Patent 6,284,149 in view of Kadomura U.S. Patent 5,266,157.

Claims 19 and 21-23 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Li et al. U.S. Patent 6,284,149 in view of Kadomura U.S. Patent 5,266,157.

Claim 20 was rejected under 35 U.S.C. § 103(a) as being unpatentable over Li et al. U.S. Patent 6,284,149 in view of Kadomura U.S. Patent 5,266,157 and further in view of Guinn et al. U.S. Patent 5,877,032.

Claim 24 was rejected under 35 U.S.C. § 103(a) as being unpatentable over Li et al. U.S. Patent 6,284,149 in view of Guinn et al. U.S. Patent 5,877,032.

#### **II. THE THREE NEWLY CITED REFERENCES**

##### **A. The Li et al. Reference**

Li et al. U.S. Patent 6,284,149 teaches a plasma etching process for etching carbon-based low-k dielectric layers in a multi-layer inter-level dielectric such as a dual damascene structure. The low-k dielectric material principally discussed is divinyl siloxane-benzocyclobutene (BCB), which contains about 4% silicon, with the remainder of the low k dielectric material being carbon, hydrogen, and a little oxygen. Also discussed is the use of SILK, a low k carbon-based dielectric material available from the DOW chemical company which contains no silicon. The BCB etch, which is used to etch via and trench openings in the BCB low k dielectric material, uses an etching gas of oxygen, a fluorocarbon, and nitrogen and no argon. In a dual-damascene

structure, the inter-level dielectric includes two BCB layers, each underlaid by a respective stop layer. An  $N_2/O_2$  ratio of between 1:1 and 3:1 produces vertical walls in the BCB. Photolithography with an organic photoresist needs a hard mask of silicon oxide or nitride over the upper BCB layer. After the BCB etch has cleared all the photoresist, the bias power applied to the cathode supporting the wafer needs to be set to a low value while the separately controlled plasma source power is set reasonably high, thereby reducing faceting of the exposed hard mask. Chamber pressures of no more than 5 milliTorr increase the selectivity of BCB over photoresist. Substrate temperatures of less than  $0^\circ C$ . increase the BCB etch rate. A low fluorocarbon flow increases the etch rate, but a minimum amount of fluorocarbon is required for the silicon component of BCB. In a counterbore dual-damascene etch, the lower stop layer is composed of nitride, and the preferred fluorocarbon is difluoroethane ( $CH_2F_2$ ). A silicon-free carbon-based low-k dielectric can be etched under similar chamber conditions with an etching gas of oxygen and nitrogen in about equal amounts but including no fluorocarbon nor argon.

**B. The Kadomura Reference**

Kadomura U.S. Patent 5,266,157 discloses a method for anisotropic etching of a fine resist pattern at a practically useful etching rate wherein micro-loading effects are suppressed. When a resist layer is etched using an  $NH_3/N_2$  gas mixture, and the temperature of a sample wafer is controlled to be not higher than  $50^\circ C$ ., a reaction product containing at least N, C, and O is said to be produced. Micro-loading effects are suppressed because deposition and sputtering of the reaction product occur competitively on the wafer surface. Since etching of the ion mode is accelerated by  $N_2$ , the etching rate as well as anisotropy is improved. There is also provided a method of supplying sulfur to a  $NH_3$ -containing etching reaction system and utilizing the yielded ammonium sulfide for sidewall protection for further improving anisotropy.

C. **The Guinn et al. Reference**

Guinn et al. U.S. Patent 5,877,032 teaches a process for device fabrication in which a pattern is transferred from a photoresist mask into an underlying layer of silicon dioxide. A plasma containing a fluorocarbon gas is used to etch the pattern into the underlying silicon dioxide layer. The plasma etch is monitored using optical emission spectroscopy to effect control of the etch process. The optical emission is monitored at select wavelengths. To control the process based on an observation of photoresist etch rate, two wavelengths are monitored. One is associated with a species that is produced by the interaction between the photoresist and the plasma, and one is associated with a species related to the plasma intensity. The ratio of the optical intensity at these two wavelengths is determined in real time during processing, and the ratio is associated with acceptable process conditions by referring to a predetermined calibration curve that associates a particular ratio with a particular photoresist etch rate for a given set of process conditions. If the ratio is observed to not be within a certain range of ratios determined to indicate acceptable process conditions, the plasma conditions are either changed to bring the ratio back within the desired range, or the process is stopped until the problem is corrected. To control the process based on an observation of contact hole etch rate, a wavelength associated with one species in the plasma is monitored at two different times during the etch. A ratio of the measured intensity at these two different times is obtained.

III. **THE INVENTION**

The invention comprises a process for etching oxide wherein an accurate and uniform amount of silicon oxide can be removed from a surface of an oxide layer, e.g., a gate oxide, previously formed over a semiconductor substrate. The oxide is exposed, in an etch chamber, to a plasma consisting essentially of a nitrogen plasma generated by a first rf power source maintained at a power level ranging from about 250 watts to about 1000 watts. At the same time, an rf bias, generated by a second rf power supply maintained at a power level of from above zero up to a power level just below a level at which sputtering of said substrate materials

would commence, is applied to the substrate support on which the substrate is supported in the etch chamber. The thickness of the oxide removed in a given period of time may be changed by changing the amount of rf bias applied to the substrate by the second rf power source through the substrate support.

#### IV. DISCUSSION

##### A. Rejection of Claims 4, 7, and 9-18 under 35 U.S.C. § 103(a) over Li et al. in view of Kadomura.

The Final Rejection states that the Li et al. reference discloses a plasma etching method to etch a silicon oxide layer 42 using a plasma containing a substantial amount of nitrogen.

The Li et al. reference teaches, with respect to the etching of silicon oxide layer 42, the formation of a hard mask from silicon oxide layer 42 by forming a resist mask 44 over oxide layer 42, and then etching *completely through* the exposed portions of silicon oxide layer 42 beneath resist mask 44. To form a hard mask, as taught by Li et al., *all* of the exposed silicon oxide must be removed, not just a fixed thickness as claimed by Applicants. Applicants have amended independent claims 4, 11, 19, and 24 to indicate that a thin silicon oxide is being formed, not an opening. Support for such amendments can be found specifically on page 5, lines 10-14, and in the example given on page 5, line 15 to page 6, line 12.

With respect to the use of "...a plasma containing a substantial amount of nitrogen", Applicants have not been able to find a specific disclosure of the etchant used to pattern silicon oxide hard mask 42. The etching of low k dielectric material divinyl siloxane-benzocyclobutene (BCB) is described as comprising a plasma composed of oxygen, a fluorocarbon, and nitrogen. However, the organic BCB material is said to only comprise 4% silicon, so this cannot qualify as the material being etched; and the described etchant gas mixture of oxygen, a fluorocarbon, and nitrogen cannot qualify as the gas for Applicants' "...plasma consisting essentially of a nitrogen plasma...".

The Office Action combines the Li et al. patent with the Kadomura patent for its alleged teachings concerning the etching of a silicon oxide layer using a nitrogen-containing plasma. The Kadomura patent, as understood, relates to the etching of one or more resist masks (2 and 4) by a dry plasma method using a  $\text{NH}_3/\text{N}_2$  gas mixture (see column 4, lines 24-25). Layer 3, formed between resist masks 2 and 4, is identified at column 4, lines 30-31, as a silicon oxide layer. Silicon oxide layer 3 is, however, apparently not etched using such a gas. Rather, column 4, lines 39-41 describes the reactive ion etching of silicon oxide layer 3. It should be further noted that column 3, lines 29-53 describes the beneficial addition of sulfur to the  $\text{NH}_3/\text{N}_2$  gas mixture used to etch the resist masks.

Thus, the combination of Li et al., who describe the use of a plasma containing oxygen, a fluorocarbon, and nitrogen to etch an organic low k dielectric material, with Kadomura, who teaches the etching of silicon oxide with a reactive ion etch and the etching of resist layers using a  $\text{NH}_3/\text{N}_2$  gas mixture (with or without the addition of sulfur), does not suggest the process of Applicants for the removal of specific thicknesses of a silicon oxide layer. Applicants' claims should be patentable over this combination of references.

**B. Rejection of Claims 19 and 21-23 under 35 U.S.C. § 103(a) over Li et al. in view of Kadomura.**

Claims 19 and 21-23 were also rejected on the combination of the Li et al. and Kadomura patents, the same combination of references used in the first grounds of rejection. Therefore, the same arguments advanced in response to the first grounds of rejection apply equally here. It should be noted in particular again, however, that the Li et al. plasma is designed to remove the BCB organic dielectric layer, not the hard mask. Presumably, no one seeking to develop an oxide etch would look to a process, such as that of Li et al., using a plasma designed to remove an organic material through an oxide mask. Furthermore, with respect to Table 1, it should be noted that the combination of etch gases taught by Li et al. for use in their process include 22-30 SCCM of  $\text{O}_2$ , 3 SCCM of  $\text{C}_4\text{F}_8$ , and 45 SCCM of  $\text{N}_2$ . This is not the same as

Applicants' etchant which is recited as "...consisting essentially of nitrogen". Such words are recited to exclude all but trace amounts of other materials such as the Li et al. O<sub>2</sub> and C<sub>4</sub>F<sub>8</sub> gases.

In this respect it must be pointed out that the teachings of Li et al., as well as those of Kadomura, include many other teachings and parameters which would tend draw or lead others skilled in the art away from Applicants' claimed invention.

C. Rejection of Claim 20 under 35 U.S.C. § 103(a) over Li et al. in view of Kadomura and further in view of Guinn et al.

The rejection states that Li et al. and Kadomura do not disclose the rf bias claimed in claim 20. Instead, the rejection turns to the teachings of Guinn et al. Guinn et al., however, teach the etching of silicon dioxide using a gas mixture which includes the use of a fluorocarbon in the etchant gas mixture. Thus, none of the cited references teach or suggest the plasma etching of a low k dielectric material using a gas mixture consisting essentially of nitrogen alone.

D. Rejection of Claim 24 under 35 U.S.C. § 103(a) over Li et al. in view of Guinn et al.

Claim 24 was rejected on the combination of Li et al. and Guinn et al. As stated above, Li et al. do not disclose the etchant gas mixture used to etch their oxide hard mask and the etchant gas mixture, which they do use to etch their organic low k dielectric material, does not consist essentially of nitrogen. Guinn et al., however, teach the etching of silicon dioxide using a gas mixture which includes the use of a fluorocarbon in the etchant gas mixture. Thus, again, the cited combination fails to disclose or suggest Applicants' claimed invention.

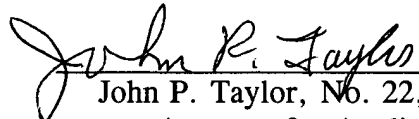
Thus, Applicants' claimed invention is not suggested by the cited combination of art. Applicants' claims should now be allowable over the cited references.

Appl. No. 09/464,297  
Amendment dated July 24, 2003  
Reply to Office Action of June 4, 2003

Docket No. 99-039

If the Examiner in charge of this case feels that there are any remaining unresolved issues in this case, the Examiner is urged to call the undersigned attorney at the below listed telephone number which is in the Pacific Coast Time Zone.

Respectfully Submitted,

  
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